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Effect of Extremity Stimulation via Vibroacoustic Therapy on Elderly Nursing Home Residents with Depression and Attentional Disturbance: A Pilot Study

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Abstract

In the present study, we aimed to investigate the efficacy of Vibroacoustic Therapy (VAT), which could be mounted on the extremities, in improving the condition of elderly Nursing Home (NH) residents with attentional disturbance disorders. We performed extremity stimulation via VAT on 10 elderly NH residents for 30 minutes a day for 2 weeks (5 days/week). The findings revealed a significant reduction in the systolic blood pressure and a substantial improvement in the Dementia Behavior Disturbance (DBD) scale and Dementia Mood Assessment Scale(DMAS) for the evaluation of dementia-related behavioral problems and depression in patients with dementia, respectively. Even though no significant improvement was observed on the Mini-Mental State Examination (MMSE), attention and calculation item (one of the sub-items of the MMSE) exhibited a significant difference. In addition, no significant differences were observed in the diastolic blood pressure, pulse, SpO2, and sleep-wake rhythm. The findings of this pilot study suggest that extremity stimulation via VAT demonstrated relaxation effects on elderly NH residents, signifying its potential in the improvement of depressive symptoms and attentional disturbance.

Keywords: Attentional Disturbance; Depression; Extremity Stimulation; Nursing Home Resident; Vibroacoustic Therapy

Introduction

Since its proposition by Skill, [1] in 1989, Vibroacoustic Therapy (VAT) has gained prominence owing to its therapeutic effects, most of which have been identified in the octave range between 40 and 80 Hz, which is the range at the center of the VAT area. VAT is a process in which vibrations are directly applied to the body in the form of low-frequency sinusoid tones in combination with selected music Standly [2] demonstrated that VAT, which combines "listening to music" with vibrotactile stimulation, resulted in substantial relaxation effects when compared with "listening to music" alone. In addition, Lundqvist et al. [3] demonstrated the efficacy of VAT in reducing self-injurious, stereotypic, and destructive behaviors among patients with developmental disabilities.

Our previous study [4] suggested that VAT mitigates the depressive symptoms in elderly Nursing Home (NH) residents. However, no improvement effect on the cognitive function was reported in that study. In this study, the device used is a mattress-type vibroacoustic device, its low-frequency (20-150Hz) components produce vibration through six vibration transducers placed near the shoulders, waist, and femur. Our pilot study [5] suggests that steam foot spas mitigate cognitive impairment, primarily attentional disturbance, potentially improving the cardiac function in geriatric impairments. The cholinergic nervous sural region, which projects from the Nucleus Basalis of Meynert (NBM)in the basal forebrain to the cerebral cortex and from the septal region to the hippocampus, dilates the blood vessels in the cerebral cortex

and hippocampus [6]. The activation of the nicotinic acetylcholine nervous system enhances the neuroprotective effect to increase the secretion of the nerve growth factor [7]. Piché et al. [8] investigated the NBM nerve activity with somatosensory stimulation (brushing to the peripheral limbs of rats) and determined the release of acetylcholine and increased blood flow in the cerebral cortex. Improvement in the attentional disturbance of hospitalized elderly patients by steam foot spas could be attributed to the activity of the NBM because of the thermal stimulation of lower limbs.

Thus, it can be hypothesized that steam foot spas improve attentional disturbance in the elderly. However, because this device uses steam (42˚C), it cannot be used in the summer in Japan. Hence, we developed extremity stimulation via the vibroacoustic device, which, in this study, is a vibration transducer that transforms low-frequency components of 20-150 Hz, which is almost the same frequency band we used in our previous experiments, into vibrations. This device is anticipated to best reflect the efficacy and safety of our previous studies.

In this study, we aimed to investigate whether VAT improved attentional disturbance symptoms in elderly NH residents.

Subjects and Method

Stimuli

We enrolled 10 elderly NH residents (3 males, 7 females; age: 80.38 ± 3.68 years) who presented with surface attentional disturbance (sub-items of the MMSE: attention and calculation, 1.5 ± 1.72/5) (Table 1). We performed extremity stimulation of VAT on all participants for 30 minutes every day for 2 consecutive weeks, except for Saturdays and Sundays. The objectives and procedures of the study were explained to all subjects as well as to their families. This project was approved by the Geriatric Health Service Facility Kiryuuen, and all subjects provided their informed consent.

Characteristic	Subjects
Age, years (mean ± SD)	80.3S ± 3.68
Sex	
Male	3
Female	7
Diagnosis	
Parkinson's disease	1
Cerebral infarction sequelae	5
Cerebral vascular parkinsonism	6
Dementia with Lewy bodies	1
Alzheimer's type dementia	2
Cerebrovascular dementia	1

Table 1: Characteristics of study participants (n=10).

This vibroacoustic device comprised four manchettes (transducer is embedded) and a headphone to separate audio signals from music into two lines. While auditory music from one of the lines was entirely available for the headphone, the other line isolated low-frequency components (20-150 Hz) and reproduced them as vibrational stimuli through four vibration transducers (a device converting electrical signals into mechanical vibrations) embedded in the manchette to the bilateral upper arm and bilateral lower leg.

Herein, we performed VAT from 15:30 to 16:00 every day based on data by Smallwood et al. [9], which proved that aromatherapy and massage given during that time of the day were most effective for patients with dementia. Similarly, our previous study also indicated that 40Hz vibratory sound for 30-minute period was most effective for PC12m3 cells [10]. All subjects in this study selected the music as per their preference.

Outcome Measure

Rating scale

We examined sadness and depression using DMAS, [11] a 24-item (score, 0-144) observational scale that is used to rate mood and functional abilities. In this scale, the first 17 items were designed to measure mood in cognitively impaired subjects and last seven to assess the cognitive and functional impairment. The mood subscale has a maximum score of 102 with a higher score representing greater dysphoria.

Furthermore, we assessed cognitive performance using the Mini-Mental State Examination (MMSE; score: 0-30) [12]. Behavioral disturbances were assessed using the Dementia Behavior Disturbance (DBD; score: 0-68) scale. [13]. In addition, we developed a 28-item DBD scale to avoid certain challenges encountered while using older instruments. Each of the 28 items was designed to be used in an interview format, with patients' primary caregivers as respondents. Each behavior was rated on a Likert-type scale with five possible responses corresponding to the frequency of the behavior in the preceding week (0, never; 4, all the time). Thus, higher scores indicated more disturbances. Notably, the reliability and validity of the Japanese version of the DBD scale has been previously established [14].

For each patient, we recorded DMAS, MMSE, and DBD at the same time before and after 2 weeks of VAT.

Examination of physical responses

Physiological responses including the tympanic temperature, percutaneous oxygen saturation (SpO_2), blood pressure, and pulse rate were assessed. Tympanic temperature was recorded using a TERUMO ear-type thermometer (EM-30 CPL; TERUMO Co., Ltd., Tokyo, Japan). All measurements were recorded on weekdays over 2 consecutive weeks (a total of 10 times). In addition, we performed each measurement in triplicates after 5 minutes of bed rest immediately after VAT, and the highest value was used for analysis. SpO_2 levels were evaluated with a finger pulse oximeter (EPOCH 30; Ubi-X Co., Ltd., Tokyo, Japan) on weekdays over 2

consecutive weeks (a total of 10 times). Furthermore, the BP and pulse were measured using an OMRON digital automatic wrist-type sphygmomanometer (HEM-632; OMRON Co., Ltd., Kyoto, Japan).

Sleeping hours and sleep efficiency

We measured sleeping hours using a wristwatch-type actigraphy (Micromini RC; Ambulatory Monitoring Inc., Ardsley, NY), which reportedly exhibits 90% or more agreement with sleep polygraphy [15], records gravitational acceleration as little as 0.01 G with pressure sensors in three directions along the X-, Y-, and Z-axes, and discriminates between sleep and wake phases from the amount of activities during gravitational acceleration. Moreover, it uses sleep-wake distinction software approved by the American Academy of Sleep Medicine [16]. We used the Sadeh algorithm as a discriminant [17,18]. We recorded measurements for 16 days, except during bathing, from 1 day before VAT until 1 day after VAT concluded. This aimed to determine each patient's circaseptan rhythm, which is a cycle comprising 7 days in which several biological processes of life resolve, for example, blood pressure and heart rate [19-21].

Data analysis

In this study, data were statistically analyzed using SPSS software (version 16.0, SPSS, Chicago, IL). The Wilcoxon signed-ranks test was used to determine significant differences in physiological responses (tympanic temperature, SpO_2, BP, and pulse) before and after VAT, and sleep-wake time (total sleep time, wake time, and nighttime sleep) of the first and second week. We considered the significance level at 0.05.

Result

Table 2 summarizes the changes in the DMAS, DBD, and MMSE scores before and after VAT. A significant improvement in depression as assessed using DMAS was noted ($P< 0.05$). In addition, a significant improvement was observed in depression and sadness, as assessed using items 1-17 of DMAS ($P< 0.05$). However, no significant improvement was observed in the overall dementia severity (items 18-24). Moreover, a significant improvement in the behavioral problems of dementia assessed using the DBD was noted ($P< 0.05$). Even though no significant improvement was observed on the MMSE, attention and calculation item (one of the sub-items of MMSE) exhibited a significant difference ($P< 0.05$). Regarding physiological responses, a significant increase in the tympanic temperature was noted ($P< 0.001$) after VAT. In addition, a significant decrease in the systolic blood pressure was noted ($P< 0.01$) after VAT. No significant change was noted in the diastolic blood pressure, pulse, and SpO_2(Table 3). Lastly, no significant change was observed in the sleep-wake rhythm (Table 3).

Assement tool	Before (mean ± SD)	After (mean ± SD)
DBD	40.00 ± 6.41	33.80 ± 10.13*
DMAS (total 24 items)	47.30 ± 28.95	33.10 ± 22.23*
:Depression and sadness (item 1-17)	32.90 ± 19.35	24.20 ± 14.08*
:Overall dementia severity (item 18-24)	14.80 ± 10.87	8.90 ± 8.94
MMSE	17.20 ± 6.19	17.70 ± 5.95
: attentional disturbance	1.50 ± 1.72	1.710 ± 1.71*
Notes: n= 10; *P<0.05		
Abbreviations: MMSE, Mini-Mental State Examination; DBD, Dementia Behavior Disturbance scale; DMAS, Dementia Mood Assessment Scale; SD, Standard Deviation.		

Table 2: Effect of VAT treatments on cognitive function, behavioral symptoms, and psychological symptoms.

Physiological responses	Before (mean ± SD)	After (mean ± SD)
Tympanic temperature (°C)	35.90 ± 0.30	36.23 ± 0.22**
SpO_2 (%)	95.84 ± 0.67	95.99 ± 0.96
Pulse (beats/minute)	67.37 ± 7.20	66.17 ± 9.06
Systolic blood pressure (mmHg)	129.48 ± 14.18	121.40 ± 14.18**
Diastolic blood pressure (mmHg)	68.15 ± 6.47	67.57 ± 8.82
Sleep-wake rhythm		
Night-time sleep (minutes)	309.82 ± 131.79	344.32 ± 132.99
Night-time sleep efficiency (%)	84.79 ± 9.36	87.92 ± 5.40
Notes: n = 10; *P, 0.05; **P, 0.01.		
Abbreviations: SD, Standard Deviation; SpO_2, percutaneous oxygen saturation.		

Table 3: Effect of VAT treatments on physiological responses and on sleep-wake rhythm.

Discussion

Falempinet al. [22] suggested that the tendon vibration (120 Hz) on the rat soleus muscle can be used as a paradigm to counteract the atrophic process observed after hindlimb unloading. When tendon vibration was applied, the soleus muscle stretched. Hence, they concluded that the protocol used this exercise is eccentric contraction exercise training. The vibration region of VAT in the present study was 20-120 Hz, which suggested that the soleus muscle demonstrates eccentric contraction exercise because it directly stimulates the lower leg triceps on both sides. These findings indicate that although VAT is a passive music therapy, it leads to strength training without putting a burden on the cardiopulmonary function. Blumenthal et al. [23] demonstrated that aerobic exercise

is an effective treatment for depression in the elderly compared with antidepressant drugs. Singh et al. [24] reported that not only aerobic exercise but also resident exercise exerts an antidepressant effect. The improvement effect on depression witnessed in 10 elderly NH residents ($P< 0.05$) in this study could be attributed to eccentric contraction exercise of the soleus muscle by the VAT stimulation. Furthermore, the improvement effect on depression seems to alleviate elderly NH patients' behavioral problems ($P< 0.05$). Furthermore, Sunderland et al. [11] reported that scores significantly correlated with the global measures of depression ($r = 0.73$) and sadness ($r = 0.65$), with highly satisfactory inter-rater reliability.

Haffeman et al. [25] reported that the resistance exercise training may reduce the central blood pressure in older adults with hypertension and prehypertension. In this study, a significant reduction in the systolic blood pressure could be attributed to the effect of eccentric contraction exercise of the soleus muscle induced by VAT stimulation.

The cholinergic nervous system, which projects from the NBM in the basal forebrain to the cerebral cortex and from the septal region to the hippocampus, dilates the blood vessels in the cerebral cortex and hippocampus. During the flow, nitric oxide is produced by vascular endothelial cells, located on the inner wall of the components of the cardiovascular system, which induces relaxation of vascular smooth muscle cells. Furthermore, it increases the cerebral blood flow, which, in turn, is induced by cerebral microvascular extensions [26]. Piché [8] reported an increase in the NBM nerve activity with somatosensory stimulation and established the release of acetylcholine and increase of the blood flow within the cerebral cortex.

In this study, the temperature inside the tympanic chamber of elderly NH residents significantly increased ($P< 0.01$) after VAT stimulation, which is presumed to be because of the NBM activity promoting the blood flow in the brain and causing an increase in the internal carotid artery temperature.

This is presumed to be due to the activity of NBM promoting blood flow in the brain, resulting in an increase in internal carotid artery temperature, which was reflected in the significant increase in the temperature inside tympanic chamber [27]. Furthermore, cholinergic neurons are involved in improving cognitive function because these neurons are involved in memory and attention [28].

These neurons activate vasodilators [29]. Vascular endothelial cells are located on the inner wall of the components of the cardiovascular system, and nitric oxide is produced by vascular endothelial cells, which induces the relaxation of vascular smooth muscle cells [26]. It increases cerebral blood flow, which in turn is induced by cerebral microvascular extensions. Cholinergic neurons are activated by somatosensory stimuli, [8,29] suggesting their activation by somatosensory stimulation, improving attention and memory. Apparently, cerebral blood flow temperature are physiological indicators that confirm this effect. Overall, the improvement of attentional disturbance in this study could be attributed to the induction and activation of the NBM by low-frequency VAT stimulation.

Conclusion

The extremity stimulation of VAT may potentially decrease depression and attentional disturbance in elderly NH residents. Nevertheless, further well-controlled, extensive studies are warranted to confirm these findings. In a nutshell, the presence of music is indispensable in promoting the effect of VAT.

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